Characterization of rock from Serra Geral Group as nutritional supplement for soils.

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Abstract. The use of rock powder as remineralizers or rocks for crops is an alternative source of nutrients to conventional fertilizers, can be used in organic farming and reduces the risk of aquifer contamination. In addition to reusing mining by-products, rock powder can act in soil rejuvenation, carbon sequestration, increasing the population of microorganisms in the soil and reducing the costs of conventional fertilization. This objective research characterized a rock from the Serra Geral Group, in southern Brazil, looking for alternatives for fertilizers and soil conditioners, since rock powders have a slow-release rate of nutrients, which are more absorbed by plants and less leached. From the chemical assessment, it was possible to identify that the rock contains more than 64% SiO_2, also containing 2.5% K_2O and 4.6% CaO and just 1% MgO. The petrography showed a large amount of volcanic glass, which favours the process of mineral manipulation and availability to the soil. X-ray diffraction shows andesine and augite, potential minerals to release magnesium (Mg), calcium (Ca) and silicon (Si), and clay mineral from the vermiculite group, in addition to a pronounced amorphous halo, highlighting the amorphous content of the sample. Based on the characterization performed, it is believed that the rock can be used to nourish soils, providing mainly SiO_2, in addition to K_2O and CaO. In addition, due to the volcanic glass, there is a great tendency for devitrification when in contact with the soil, facilitating the release of nutrients.

Keywords. Rock powder, soils, minerals, nutrients, stones for crops.

1. Introduction

The agriculture in the future will face significant challenges in ensuring sustainable food production systems, due to the growing global demand for food, shortages of inputs, soil depletion and environmental adaptations. To overcome these challenges, it is essential to adopt sustainable and efficient technologies, developing inputs that promote soil fertility and plant nutrition without polluting soil and water resources. To this end, it is necessary to search for raw materials that are safe for flora and fauna, at a reduced cost and that act as alternatives for the nutrient supply to plants and the restoration of soil health [1,2].

A promising alternative, the application of rocks in powder form to the soil, known as rock fertilization or rocks for crops, consists of the use of ground rocks in agriculture and represents a more economical alternative compared to traditional chemical fertilizers. Rockfill can be used by organic food producers and is also attractive to the public interested in consuming healthier foods, produced with less environmental impact [3]. Applying fresh minerals renews soils through the process of enhanced weathering, with the contribution of new surfaces, release of nutrients and soil correction [4,5]. Since the temporal scale of soil formation takes thousands of years, the application of ground rocks can considerably accelerate this process, as it is equivalent to the natural stage of physical weathering, but on a much shorter time scale [5].

Rock powder is a viable alternative for fertilization in tropical soils, and offers benefits such as increased cation exchange capacity, pH correction, non-salinization and non-acidification of the soil, reduction of phosphorus adsorption and leaching losses [6]. Unlike conventional fertilizers, rock powders used as remineralizers or rocks for crops have partial dissolution, that is, new mineral phases are generated, promoting physical, chemical and biological changes in the soil in the long term [7].

Among the numerous types of rocks that can be used in soil remineralization, volcanic rocks have great potential [8,9]. According to Theodoro, Leonardos & Almeida [4], researchers studied the basalts of the Serra Geral Group (SGG) because they have promising geochemical characteristics: composed of calcic plagioclase, pyroxenes and olivines and fine grainedness. It may also contain less mafic terms and vitreous materials. The Geological Map of the state of Rio Grande do Sul [10] reports that the SGG is composed of basalt flows, andesite basalts, rhyodacites and rhyolites, with Botucatu sandstones intercalated at the base and litharenites and volcanogenic sediments from the middle to the top of the sequence. SGG basalts and diabases often contain various types of natural zeolites [11, 12], which have a three-dimensional structure organized in crystalline networks formed by aluminum and silicon tetrahedrons, which induce negative charges, in addition to enhancing water retention and release and favoring cation exchange without altering the zeolite structure [11,13].

According to Bergmann et al. [14], Bergmann [12] and Hoff et al. [15], the vast majority of rocks in the SGG have a sum of bases (K_2O+CaO+MgO) between 14 and 17% and are sources of macronutrients (Ca, Mg and Si), in addition to micronutrients (Mn, Fe, Cu, Zn) in excellent levels for plant nutrition. According to the authors, the vast majority of rocks in the SGG do not present restrictions regarding toxic elements. According to Bergmann et al. [3] and Bergmann [12], dacites and rhyolites are environmental rocks that are sources of potassium, with availability in soils facilitated by their glassy textures, and the possible presence of devitrified materials also favors reactivity when applied to soils [1]. Amygdaloid basalts, zeolites and spill-top breccias also present prominent lithotypes, as they implement the capacity for cation exchange and as an acidity correction in soils [12].

To select the most appropriate rocks, it is essential to evaluate the lithochemistry and petrography of the samples [3]. Tarumoto, Rossato and Crusciol [16] used basaltic spills from the SGG, formed, according to the authors, by 55% plagioclase, 35% pyroxene, 5% magnetite, 5% volcanic glass and 1% apatite as a soil remineralizer. Hoff et al. [17] used basalt rock powder as an input in the recovery of degraded areas as an input in vine cultivation, obtaining good results in cultivation. The relative reactivity potential of the minerals forming volcanic rocks is greater in silicate minerals rich in Ca and/or Mg, mainly anorthite, followed by pyroxene, olivine, amphibole and biotite [5].

In view of the above, this research is justified by the possibility of using SGG rocks as a complement of nutrients for soils, based on lithochemical and petrographic information, aiming to reduce the consumption of soluble fertilizers and pesticides, consciously taking advantage of agricultural areas.

2. Trial program

A sample of acidic rock from SGG was selected, initially treated as pichtstone (glass breccia) found in a deposit belonging to an active mining company in southern Brazil, treated as undesirable waste by the mining company and discarded. In the field, the rock was extracted manually, using a chisel and hammer. In the laboratory, they were washed to remove possible contaminants and dried in an oven for 24 hours at a temperature of 100 °C.

For petrographic analysis, the clean and dry samples were used to produce thin sections made in accordance with NBR 7211 [18] and NBR 7389-2 [19]. The sample was sawn, glued to a glass slide, lowered to 0.3 mm and polished. The slides were described with the assistance and supervision of geologist and professor of mineralogy and petrography, Andrea Sander, from the Universidade do Vale do Rio dos Sinos (Brazil). A trinocular, transmitted light, plane-polarized petrographic microscope, model Nikon Eclipse 50i POL, was used. Based on the petrographic slide, it is possible to visually evaluate the minerals present. Also from the petrographic data, it is possible to determine the most favorable granulometry for weathering and to verify which minerals have physical and chemical stability conditions for the release of certain oxides and elements in the exogenous cycle within compatible time frames [3].

The quantitative chemical evaluation was performed using X-ray fluorescence in an Epsilon 1 Panalytical equipment, and the minerals that constitute the samples were verified with an Empyrean Panalytical X-ray Diffractometer (XRD). However, before starting the chemical and mineralogical evaluation, the rocks underwent a comminution process, consisting of the following steps: laboratory jaw crusher, to reduce the samples to a size equal to or less than 5 mm; ceramic alumina disc mill for 10 minutes; ball mill for 30 minutes; segregated in a sieve with a mesh opening of 45 μm manually, exerting mechanical force with the aid of a brush in circular movements; drying in an oven at 100 °C for 24 hours; cooling in a desiccator; and, finally, reserved in hermetic packaging.

3. Results

The rock analyzed is of the volcanic igneous class, being a glassy basaltic rock or glassy andesite. It is a melanocratic rock with a black color in the fresh fracture, where conchodal fractures stand out, not following natural separation planes and a glassy shine, attesting to low crystallinity, which is favorable for use in soils, since minerals with low crystallinity act as an interaction surface as they activate the restructuring of soil microbial communities [5].

Since it is a microporphyritic rock with an aphanitic matrix, where crystals cannot be individualized without the use of a microscope, Figure 1 shows a photomicrograph of sample 1, where it is possible to identify a wide glassy matrix, irregular contours with corrosion gulfs, microporphyritic texture with few microphenocrysts of plagioclase (pl) and clinopyroxene (px) immersed in volcanic glass. The lower degree of adjustment of the crystalline structure that volcanic glasses present favors the degradation process [3].

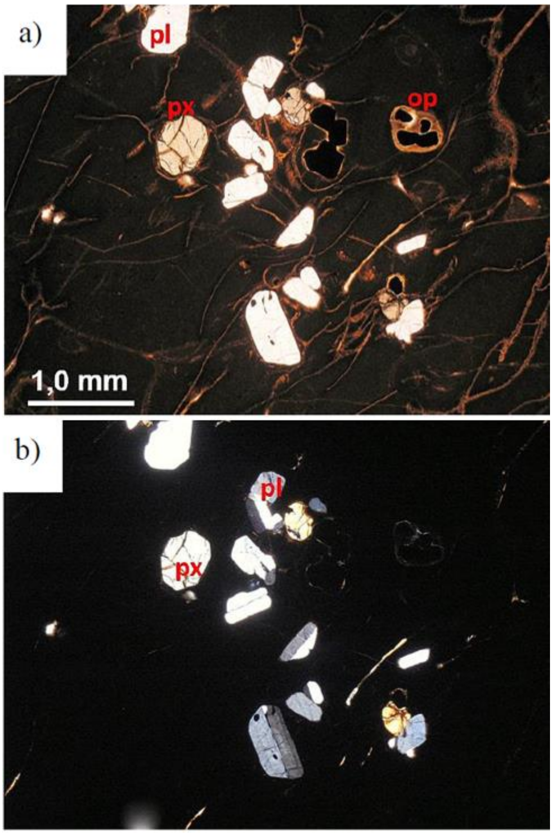

Fig. 1 - Petrographic photomicrograph of the rock under analysis, 25X magnification and 1.0 mm graphic scale, (a) plane polarized light and (b) crossed polarized light

According to Bergmann et al. [3], volcanic glass rapidly degrades when exposed to the elements, causing a devitrification process. Devitrification results in a mixture of clay minerals and zeolites, which facilitate soil cation exchange. Hoff et al. [17] also state that devitrified materials favor soil reactivity and ensure the presence of clay minerals with high cation exchange capacity. The opaque mineral (op) identified in Figure 1 is hematite, but magnetite and brownish minerals may also occur, possibly a clay mineral from the Vermiculite Group, with low or no birefringence, indicating low crystallinity. This low crystallinity, indicated by the amorphous halo, as well as the constituent minerals, can be seen in Figure 2.

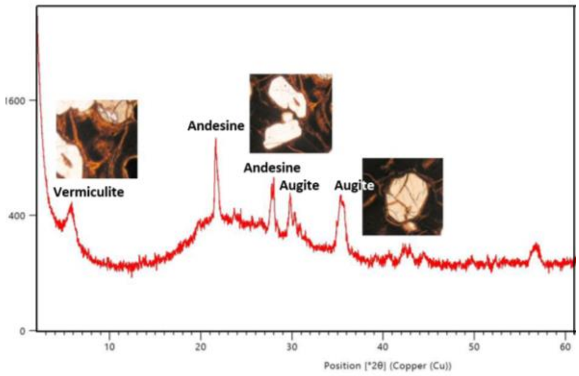

Fig. 2 - X-ray diffractogram with the main minerals identified

The minerals present are andesine and augite, both minerals of the silicate class, belonging to the plagioclase subgroup, commonly found in basalts, as described by Amin et al. [20] and clay mineral of the vermiculite group, corroborating the petrographic description (Figure 2). According to Martinazzo et al. [2], calcic plagioclases (such as andesine, which occurs in acidic to intermediate volcanic magmatic rocks, shown in Figure 2) and pyroxenes (augite is the most common pyroxene identified in rocks, common in ultramafic rocks) are susceptible to weathering and can release magnesium (Mg), calcium (Ca) and silicon (Si). Dacites and rhyolites have a greater quantity of potassium feldspars, sodium plagioclase (andesine) and quartz, with a higher silica content and the presence of potassium (K) and sodium (Na) alkalis. According to the authors, the dacite used by Bergmann et al. [3] has strong evidence of potassium release due to the glassy features observed in the petrography. In Figure 2, it is still possible to identify an existing amorphous halo, proving the low crystallinity.

Table 1 shows the chemical composition of the rock, through X-ray fluorescence, with a predominance of SiO_2. In addition to SiO_2, the K_2O content stands out, which is essential for soils.

Tab. 1 - Chemical composition of the rock, list of main oxides that make up the sample and percentage by mass.

SiO_2 (%)	64,954
MgO (%)	1,015
Al_2O_3 (%)	13,98
K_2O (%)	2,526
Fe_2O_3 (%)	7,585
P_2O_5 (%)	0,609
CaO (%)	4,614
Cl (%)	0,617
TiO_2 (%)	1,102
MnO (%)	0,143

Acid glasses with high silica content, as shown in Table 1, have the potential to make K and Si available [12]. Also having a high SiO_2 content, the dacitic rock used by Grecco et al. [1] has 67.45% SiO_2, 12.44% Al_2O_3, 4.63% K_2O, 2.22% CaO, 2.44% Na_2O, 3.02% Fe_2O_3 and 0.73% TiO_2.

Although silicon is not considered an essential element for plant development, it provides numerous benefits [21]. It has been proven that supplementing crops with Si-rich materials benefits crops in terms of biochemistry, mechanical resistance and reduction of stress caused by salinity and water deficit [22]. According to Epstein [23], plants that receive Si as a supplement have physical defense, through the deposition of hydrated amorphous silica in the cell wall, and chemical defense, through secondary metabolites that repel insects in addition to minimizing damage caused by heavy metals and extreme temperatures. Indirect effects can also occur when silicate rock powder is used, due to the sorption and desorption processes mediated by the element silicon [2].

4. Conclusions

Aiming to implement resilient agricultural practices that act on soil nutrition, increasing crop productivity, and protecting and conserving flora and fauna, this research evaluated the petrography and chemical composition of an acidic volcanic rock from GSG, containing a high amount of silica and volcanic glass. It is inferred that the volcanic glass present in the analysed rock can increase the availability of nutrients consumed in the soil/plant nutrition process. Even if only theoretically, petrographic and chemical evaluation can help in the selection of rock powders for application in soils. However, in addition to chemical and petrographic characterization, it is essential to carry out agronomic performance tests.

5. Acknowledgement

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